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DESIGNING AND COMPARING AIR TRAFFIC CONTROL CONSOLES

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and A.V. Morier

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DESIGNING AND COMPARING AIR TRAFFIC CONTROL CONSOLES

CONCEPTION DES CONSOLES DE CONTRÔLE DE LA CIRCULATION AÉRIENNE

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ABSTRACT

This report compares procedures used to elicit the opinions of experienced air traffic controllers with regard to the design of air traffic control workstations. Three basic procedures were studied: construction of dummy workstations by the controllers using models of existing displays and controls, evaluation of pre-designed work-stations, and questionnaire responses. The first procedure appeared to produce the most useful and consistent results. We do not conclude that workstations can be designed by this method, but that the method produces valuable data for use by a professional designer.

RÉSUMÉ

Le présent rapport compare les méthodes utilisées pour recueillir les opinions de contrôleurs de la circulation aérienne expérimentés quant à la conception de postes de contrôle de la circulation aérienne. Trois méthodes de base ont été étudiées: construction de postes de travail fictifs par les contrôleurs au moyens de modèles d'écrans d'affichage et de tableaux de commande existants, évaluation de postes de travail de conception pré-établie, réponses à des questionnaires. La première méthode a semblé donner les résultats les plus utiles et les plus cohérents. Nous ne concluons pas que les postes de travail peuvent être conçus selon cette méthode, mais que la méthode produit des données utilisables par un concepteur professionel.

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DESIGNING AND COMPARING AIR TRAFFIC CONTROL CONSOLES

1.0 INTRODUCTION

In designing a workstation one must consider several factors which invariably affect the performance of the operator. While an operator's cognitive and motor capabilities appear to be unlimited, the total amount of information impinging upon the individual at a given time may actually exceed these capabilities. To this end, assessing human capabilities for a given task, optimimizing the use of cognitive resources, and enhancing efficiency in cognitive and motor processing are important goals for the designer, engineer, and the ergonomist, particularly for tasks in which catastrophic events may occur. Ensuring that controls and displays are readily accessible and that they induce little (if any) error is a high priority. This is a simple matter when only a few controls and displays are required on a console, but becomes quite complex when many controls and displays are used.

We review a few of the numerous guidelines to follow pertaining to control and display selection and design, restricting ourselves to those aspects relating to the JETS[1] console.

1.1 Spatial Location

Spacing between controls depends upon their size, which and how many parts of the body the operator is to use, whether actions are sequential or simultaneous, whether they are of free or fixed order, whether feedback is present or absent, and whether there is visual dependence or independence.

Controls and displays should be arranged on the basis of functional priority. A control which is critical, such as an emergency button or power switch, should be set apart from other controls. Secondary controls and displays, such as those used for lighting and temperature regulation, may be assigned to less accessible positions.

Priority should be assigned first to the primary visual tasks, and secondly to controls associated with these visual tasks, with controls located near the displays they affect. Then one must consider whether controls are within functional reach, whether they have adequate clearances from other controls, and whether arms and limbs can be rested or will fatique.

Controls are usually placed directly under the associated display. If space is limited and controls and displays must be separated they should be configured into matrices with a correlated logical arrangement. For example, certain controls may have to be activated in a particular order or sequence, and these should be arranged in a manner which requires a left-to-right response sequence, this being similar to reading. Controls and displays serving the same functions should be grouped together, particularly if they are operated by one individual.

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[1] Joint Enroute Terminal System

Other criteria to consider are sequence and frequency of use, and similarities among controls.

1.2 Feedback

Most operating systems are closed-loop in nature. The operator compares controls and displays and feedback in the system ensures that the operator is aware that a response was made. For example, when an air traffic controller is communicating to a pilot a coloured light may indicate an open channel, or each visual display may contain a coloured light to indicate that the display is operating. More elaborate feedback may provide information on whether or not the response was correct. Important considerations are what form of feedback (visual, auditory, or tactile) is present, and whether this type of feedback is appropriate for the task, and whether it provides unique, redundant and useful information.

1.3 Errors

Confusing one control or source of information on the display with another may lead the operator to activate an incorrect response. Displays and controls should be coded and positioned to avoid this. One avoidance technique is to increase distinctiveness, perhaps by using different types of switches (knobs, dials and toggles) or different coloured buttons. A second technique is to place high priority controls and displays separately from less critical controls and displays.

1.4 Summary

These remarks serve to introduce the subject of control and display design. For further discussion of these points see Huchingson, 1981 and Kantowitz, et al., 1983.

2.0 DESIGNING AN AIR TRAFFIC CONTROL CONSOLE

A continuing task of the Research and Experimentation Centre of Transport Canada is to improve the layout of air traffic control workstations and to move towards a common design. The existing JETS system served as the starting point of the present study.

In this study we endeavored to layout a workstation by requesting experienced air traffic controllers to construct their own consoles. They positioned, on a blank console, exact-scale models of the displays, control devices and ancillary equipment presently used in terminal control unit workstations. This approach allowed us both to design a new workstation and to determine whether this method provided a viable approach to the general problem of designing workstations.

The study used four procedures in the following order.

(1) Subject-design procedure: controllers designed the workstation by positioning the models on the blank console.

(2) Experimenter-design procedure: controllers rated and ranked four photographs of experimenter-designed consoles.

(3) Subject-redesign procedure: controllers modified their previous designs following evaluation of the experimenter-designed consoles.

(4) The controllers answered a questionnaire.

3.0 METHOD

3.1 Apparatus

The study used moveable exact-scale models of all except three of the controls and displays presently occupying the existing front area of a JETS workstation, twenty-eight models in all. The three exceptions were the flight strip board, the radar screen and the computer readout device which in this experiment remained at fixed locations on the blank console. A magnet placed on the back of each model facilitated its positioning on to the metallic front panel of the blank console, and each model was labelled for identification. The models are listed in Appendix 1 and all except the video information panel are illustrated in Appendix 2. The dimensions of the blank console are given in Appendix 3.

One of us (AVM) designed four different console configurations using the twenty-eight models. These were designated Configurations A, B, C and D, and 60 x 40 cm photographs of each were prepared (Appendices 4-7). In all four configurations certain models were grouped together:

- VHF[2] direction finder and emergency VHF transceiver
- runway visual range monitor and digital altimeter
- two large wind indicators and analog altimeter
- radio frequency modules and hotline modules
- quick action pad, alpha-numeric key pack and numeric function panel, which together formed the radar keyboard unit
- power switch, ILS monitor and navids monitor
- direct access modules, telephone dial pad, CCFM and speaker.

In all four configurations the shelf contained both the radar keyboard unit and the QWERTY[3] keyboard. Configurations A and B were similar in that the shelves were occupied by other models in addition to the keyboards, and Configurations C and D were similar in that the shelves were almost clear except for the keyboards. Configurations A and B differed in that one of the two top quadrants was essentially empty. Configurations C and D differed in that the large wind instruments, analog altimeter and ILS monitor were interchanged between top quadrants.

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[2] Abbreviated model names are given in Appendix 1.

[3] In this experiment we used a QWERTY keyboard and an ABCD keyboard (an alpha function panel). JETS consoles actually carry two ABCD keyboards.

The fourteen-item multiple-choice questionnaire focussed on the characteristics of the models, the amount and type of information supplied to the controllers, and the positions of the models on the console (Appendix 8).

3.2 General Procedure

Before entering the test room subjects were briefed on the objectives and procedures of the study, and the experimenter recorded each subject's name, age, and number of years and type of experience.

Subjects were presented with written instructions before each procedure and given five minutes to read them. All subjects followed the procedures in the order subject-design, experimenter-design, subject-redesign, and questionnaire.

3.2.1 Subject-design and subject-redesign procedures

At the beginning of the test session all models were placed on a table adjacent to the blank console, and in the same arrangement for each subject. Subjects were requested to design a console with the expectation that they would have to use it to control air traffic. They could select models in any order. After each subject had completed the task the experimenter photographed the console using a 35-mm format camera which was kept set up with lenses fixed and tripod in the same location for each subject.

Subjects were tested one at a time, and were told they had twenty minutes to complete the procedure, although the experimenter was in fact prepared to allow unlimited time. Pilot work showed that no more than twenty minutes were required to complete the task, and no subject exceeded this. The experimenter remained in the room during testing to answer questions and provide assistance, although the experimenter kept interaction with the subject to a minimum.

For the subject-redesign procedure, subjects returned to the console, as it had been left at the subject-design procedure, and were given the opportunity to modify their original designs.

3.2.2 Experimenter-design procedure

In the second procedure photographs of Configurations A, B, C and D were presented one at a time to the subjects. The order of presentation across subjects was counterbalanced.

Each configuration was rated on a 10 cm linear scale marked with a midpoint indicator and end-points designated least satisfactory on the left and most satisfactory on the right. Subjects used the scale to respond to the question "How happy would you be working at this station?" by marking the scale at a position corresponding to their degree of satisfaction. After rating the four configurations in turn, subjects were presented with all four photographs and asked to rank them in order from most preferred to least preferred.

3.2.3 Questionnaire

Subjects were given a copy of the multiple-choice questionnaire on which they circled their answers.

3.3 Subjects

Twelve persons, who included controllers from the Western Region and controller-instructors from the Transport Canada Training Institute in Cornwall, Ontario, voluntarily participated as subjects. Half of the subjects had previous operational experience on JETS and half on other equipment. They were all right-hand d males, ranging in age from 30 to 59 years with a mean age of 42 years, and an average of 16.5 years experience in various aspects of air traffic control.

4.0 DATA COLLECTION AND ANALYSIS

4.1 Subject-Design and Subject-Redesign Procedures

In order to analyze the data from the subject-design and subject-redesign procedures we prepared a 60 x 40 cm enlargement of each console photograph and superimposed it with a plastic grid marked in units of 2.5 cm. From this we determined the location in x-y coordinates of the centre of each model. Whenever the centre was located on a horizontal or vertical line the coordinate chosen was the one immediately up or to the left.

While there were twenty-eight distinguishable models some could be split, with subjects putting one part in one location and the other part in another location. In three cases nine or more subjects had done this, so we decided to treat these as distinguishable models, giving us data for thirty-one models. The three cases involved the telephone dial pads, the direct access modules and the common circuit and function modules.

We calculated mean, modal and standard deviation values of the x- and y-coordinates for each model in each procedure. Table 1 shows distributions of standard deviations of both coordinates for all models, depicting the amount of agreement for the subjects' chosen locations for each model on the two axes.

4.2 Experimenter-Design Procedure

For each of the experimenter-designed configurations we measured the subjects' ratings along the scale in millimetres and prepared frequency histograms depicting the number of subjects selecting particular ratings along the scale.

For subjects' rankings the configuration in the first position was assigned a rank value of one, the configuration in the second position a rank value of two, and so on. We prepared histograms of the rankings and calculated means and standard deviations.

Table 1. Distributions of standard deviations of x- and y-values.

	horizontal values (x)		vertical values (y)	
standard deviation (2.5 cm)	procedure		procedure	
	design	redesign	design	redesign
0.0 - 0.50	***	*	*****	*****
0.51 - 1.00	*	****	*********	*******
1.01 - 1.50		**	****	*******
1.51 - 2.00	**	*	******	****
2.01 - 2.50	***	*******	**	*****
2.51 - 3.00	****	****	*****	***
3.01 - 3.50	*******	***		
3.51 - 4.00	****	***		
4.01 - 4.50	*	**		
4.51 - 5.00	**	*		
5.01 - 5.50				
5.51 - 6.00	**	***		
6.01 - 6.51	**			

4.3 Questionnaire

Subjects' responses were tabulated and the questions were sub-divided into categories based on the amount of agreement.

5.0 RESULTS

The experimental sessions ranged in duration from 50 to 75 minutes. Subjects took approximately 10 minutes to be instructed, 10-20 minutes each to design and to redesign the consoles, 10-15 minutes to rate and rank the experimenter-designed configurations, and 10 minutes to answer the questionnaire.

5.1 Subject-Design and Subject-Redesign Procedures

Table 1 shows that no standard deviation for y-values exceeded a value of 3.0, indicating that subjects generally showed high consensus in locating models along the vertical axis. For this reason we used mean values to specify the agreed location of each model. Standard deviations for x-values were more scattered, indicating less consensus, and so for the horizontal axis we used modal values to specify the agreed location of each model.

On the basis of the distributions, models were divided into three categories by standard deviation (less than 1.51, between 1.51 and 5.0, and greater than 5.0) to reflect the degree of consensus (high, medium and low) in locating models along the horizontal axis. Models located with high consensus were the video information panel selector switch, numeric function panel, quick action panel, radio frequency modules, direct access modules (both parts), and data strip container.

Models located with low consensus were the large wind indicators, altimeter, and one of the common circuit and function modules. All other models were located with medium consensus (Appendix 9).

The major differences between agreed locations for the subject-design and subject-redesign procedures were in terms of the locations chosen for the large and small wind instruments, the digital clock, the emergency VHF transceiver and the VHF direction finder. In the results for the subject-design procedure the chosen locations for these last two models did not overlap, but for the subject-redesign procedure they did.

Figures 1 and 2 show, for the subject-design and subject-redesign procedures respectively, the agreed locations for all models, including the clutter produced by overlapping models where the results demand. The greatest amount of overlap occurred in the centre of the console, where several models overlapped one another, at times three models deep.

Aside from the confusion in the centre, we found that overlapping was restricted to certain models, and sometimes occurred between pairs of models. Thus the emergency VHF transceiver overlapped with the VHF direction finder, the large wind instruments with the analog altimeter, and the hotline modules with either the CCFM or one telephone dial pad. However, the digital clock, the runway visual range monitor and the digital altimeter overlapped other models with no apparent pattern or pairing.[4]

We constructed a final design based on the data for the subject- redesign procedure, trying to deal with the overlaps by moving as few models as possible. If models overlapped in locations other than the centre of the console, we relocated the top-most model by placing it in the nearest empty location on the console.

We placed the large wind instruments below the altimeter because they had been shown to be interchangeable along the horizontal axis. We resolved the clutter in the bottom left quadrant by moving the digital altimeter, the runway visual range monitor and the small wind instruments a little towards the top left quadrant.

The multiple overlaps in the centre were not resolved. Subjects usually placed the navids monitor, the digital clock, the ILS monitor, the speaker and loudspeaker, the lamp test module, the radar control box, and the power switch in this area. This suggests that these devices are those which need to be available to two controllers operating at the same workstation.

---

[4] Figures 1 and 2 do not show all the models because several were overlapped and obscured, but the figures indicate which these are. In Figure 1 the navids monitor, the ILS monitor, the lamp test module, the radar control box, the power switch, and the speaker and loudspeaker are shown, but the VIP selector switch is not shown as it was located underneath the radar control box. In Figure 2 the radar control box overlapped the lamp test module, the power switch, the navids monitor, the ILS monitor, the loudspeaker, and the VIP selector.

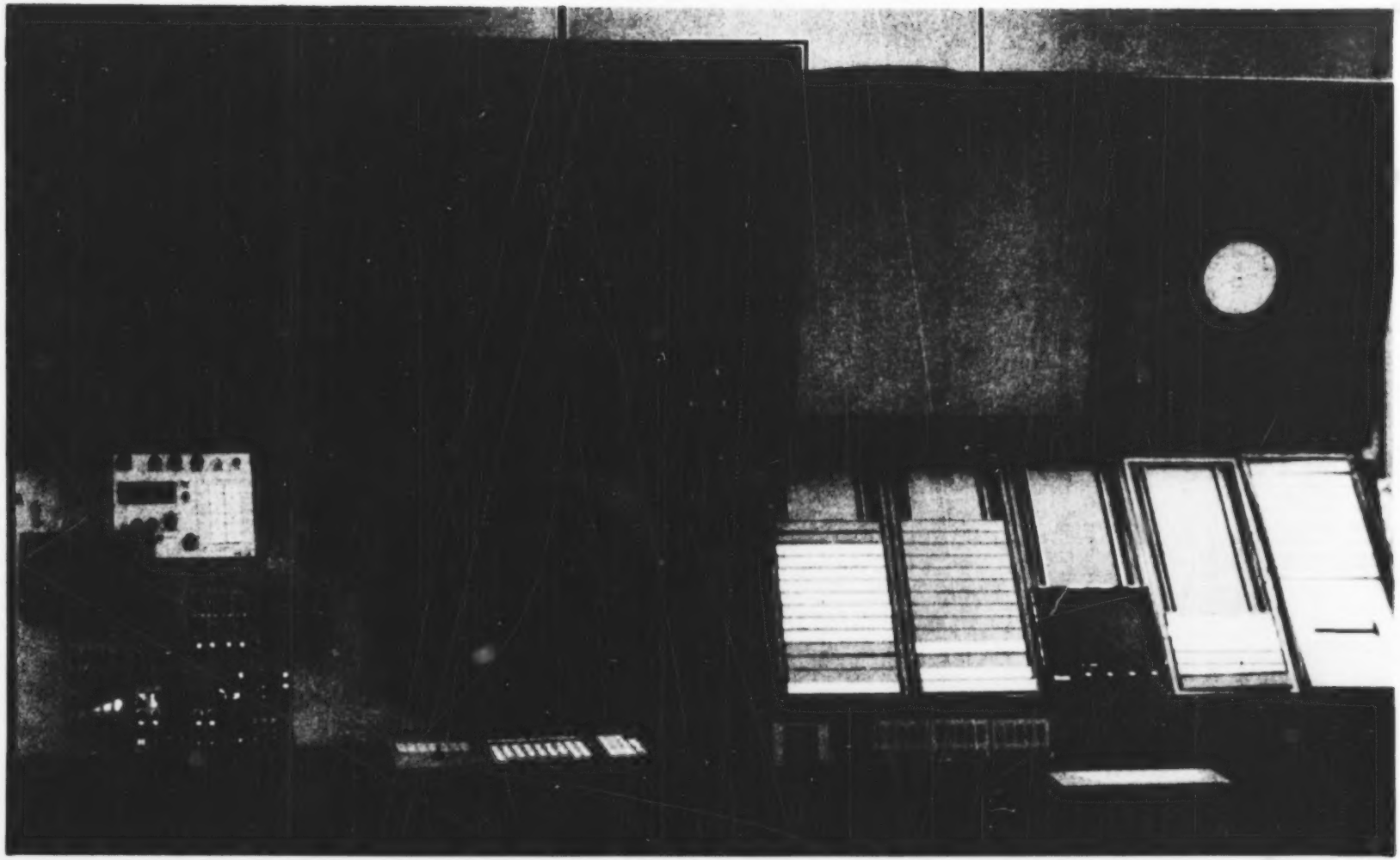


Figure 1. Agreed model locations based on subject-design procedure

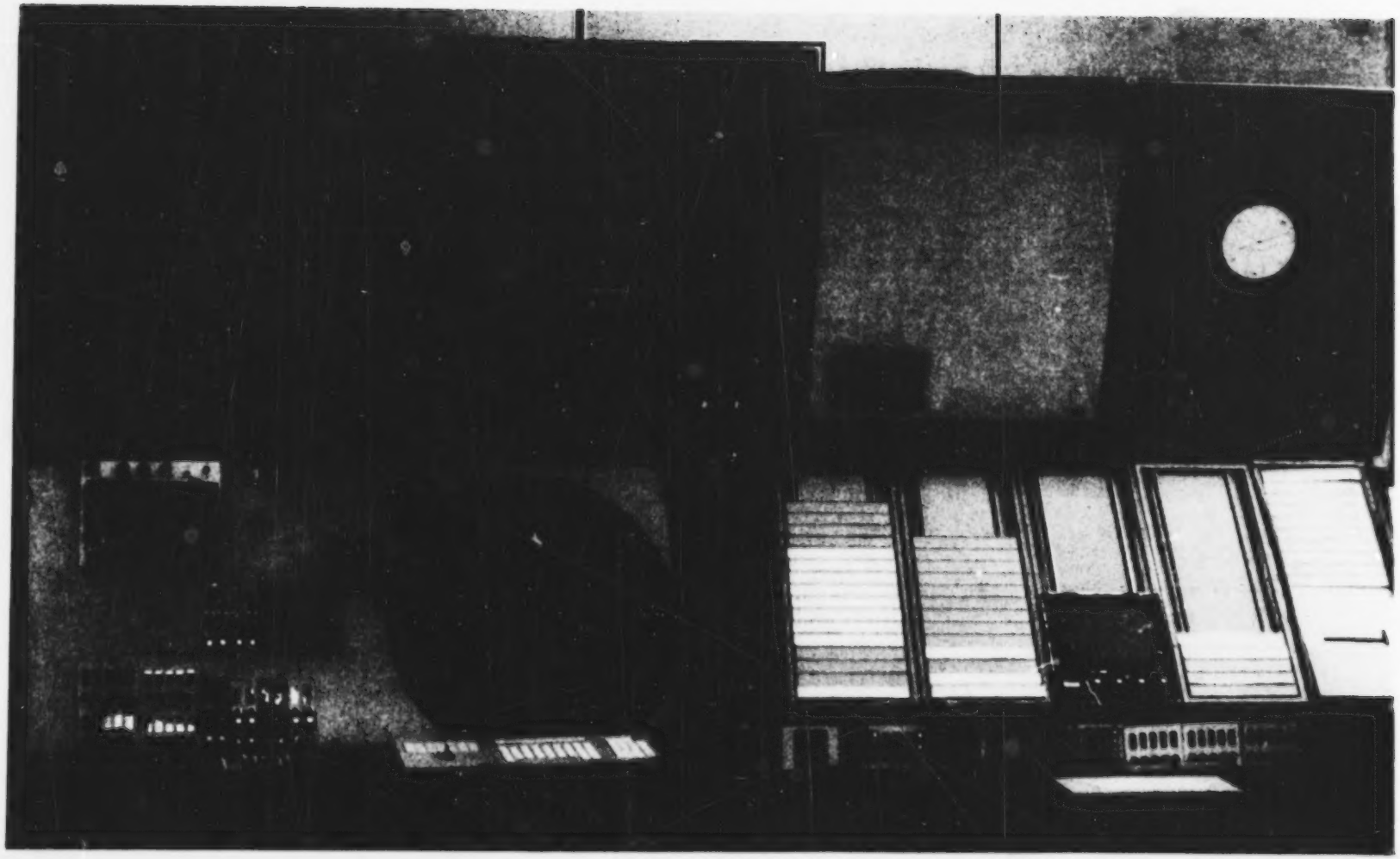


Figure 2 Agreed model locations based on subject-redesign procedure

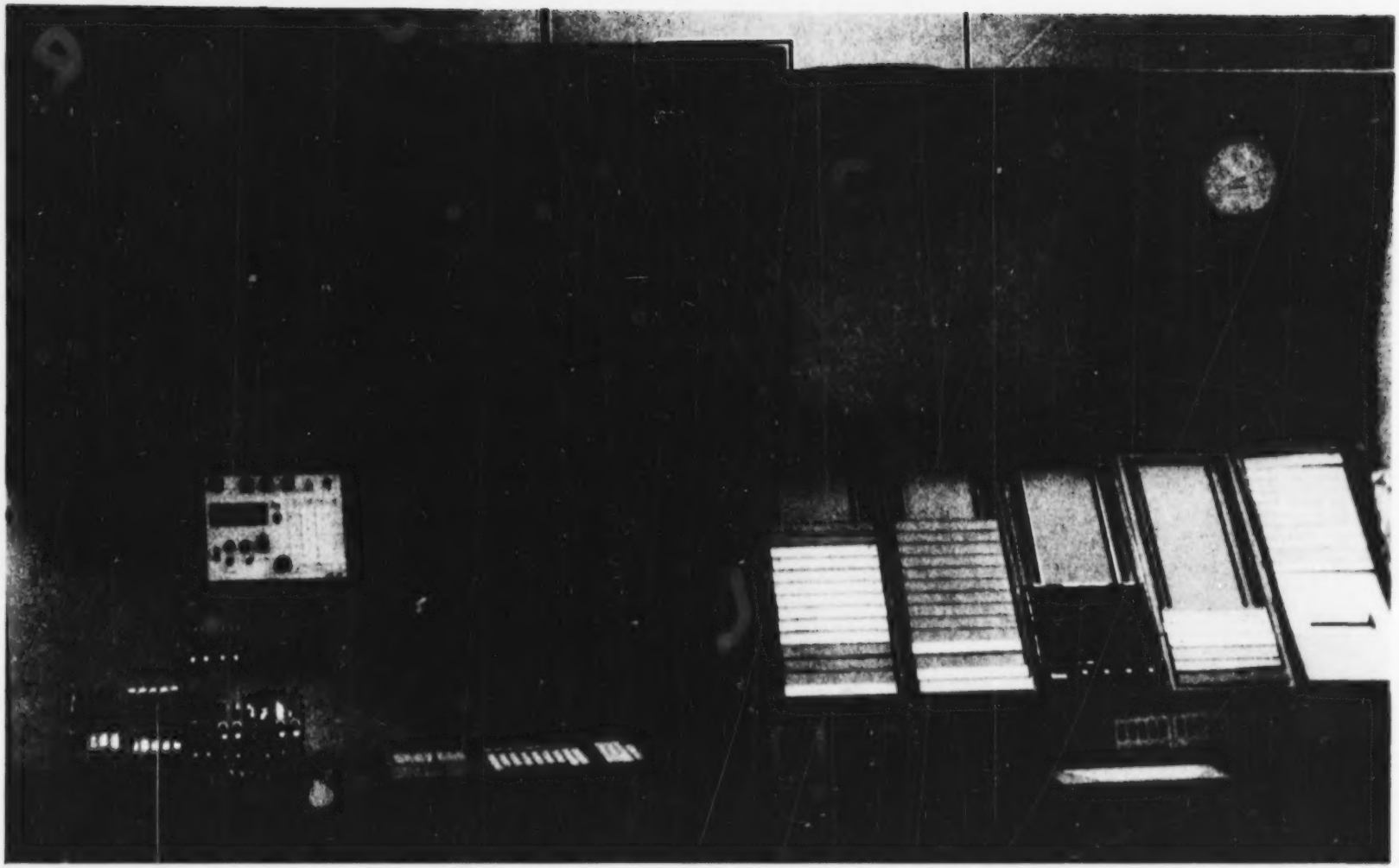


Figure 3. Final design following adjustments by experimenters.

5.2 Experimenter-Design Procedure

Table 2 shows that ratings for Configurations A, C and D grouped around the midpoint of the scale at a value of about 5.0, while ratings for Configuration B were generally more scattered. Ratings for Configuration C showed the highest, and those for Configuration B the least consensus. The results suggest that subjects' perceived midpoints on the scale were the actual midpoint, although we may have biased the ratings by marking the midpoint.

Table 2 also shows subjects' rankings for all configurations. The overall order from most to least preferred configuration was A D B C. Configuration D was ranked equally as often in the first and third place. The standard deviations show that highest consensus was on ranking Configuration C.

Table 2.
Distributions of ratings and rankings for experimenter-design procedure.

	Configuration			
	A	B	C	D
rating (mm)				
0 - 10		*		
11 - 20		*		*
21 - 30	*	***	*	**
31 - 40	*	*	***	**
41 - 50	******	**	***	**
51 - 60	*		****	***
61 - 70	*	*	*	*
71 - 80		**		
81 - 90	**	*		*
91 -100				
mean	5.43	4.35	4.68	4.60
s.d.	1.18	2.55	1.12	1.96
ranking				
1	*****	***		****
2	**	***	*****	**
3	**	**	****	****
4	***	****	***	**
mean	2.25	2.58	2.83	2.33
s.d.	1.29	1.24	0.64	1.15

Configuration A was ranked highest, and also marginally surpassed Configuration C in rating because, although their ratings were equally dispersed, Configuration A was twice rated highly to an extent that Configuration C was not. We might reasonably conclude therefore that Configuration A was rated and ranked first.

However, the results for rating and ranking do not agree for all configurations and, since they do not provide the same information, we must conclude that for purposes of design one of these methods is unacceptable. It is not possible to say, on the basis of the present results, which method is better.

5.3 Questionnaire

The numbers of responses made to the questionnaire items are given in Appendix 8. All subjects preferred a modified wrap-around type of workstation of the kind used in our experiment, and all preferred a circular radar screen with coloured information (Questions 1, 2 and 6). The responses to these, as to all questions, were based on experience outside the experiment.

There was considerable agreement (by nine or more subjects) on Questions 5, 9, 10, 11, 12 and 14. Subjects agreed that the operational information display system was of adequate size, that the communication panel required more incline but had adequate width, that a digital clock was needed at the workstation, that the keyboards should be raised from the console table and inclined rather than imbedded and laid flat, and that a bar-type foot switch was preferable to a pedal-type.

There was little or no agreement on Questions 3, 4 and 8, that is on the size and position of an additional radar screen (14 inches or 20 inches, and above the present radar screen or the data board), and on whether wind direction and speed displays should be digital or analog.

Seven of the twelve subjects preferred the data strip container to be on the left side (Question 13). Three subjects preferred it to be divided and placed one at each side of the console.

In responding to Question 7 all subjects agreed that almost all information should be colour-coded.

6.0 DISCUSSION

6.1 Subject-Design and Subject-Redesign Procedures

In designing the workstation subjects did not use the total console but left the shelf mostly vacant and positioned most models in the bottom left quadrant and along the midline between the right and left halves.

In the subject-redesign procedure they chose different locations for the large wind instruments, the digital clock, one of the CCFM's, and the four direct access modules. The locations for the remainder of the models were unchanged from the subject-design procedure. To this extent subjects kept to their original ideas and either were not influenced by the experimenter-designed configurations, or could not be bothered to make the necessary changes.

We considered whether disagreements between subjects were associated with certain models, but concluded that, generally, disagreement was related to areas on the console rather than models. In particular there was confusion in the mid-line area between the right and left halves of the console and most subjects placed several models in this area, limited only by space.

The large wind instruments were positioned in one of two locations, either the top left quadrant or the top right quadrant of the console, although the precise horizontal location varied. These models appear to be interchangeable in terms of position. Conversely, subjects agreed on the vertical location of the CCFM but not on the horizontal location.

6.2 Experimenter-Design Procedure

Overall, Configuration A was rated highest and ranked first, and Configuration B rated lovest and ranked last. The major differences between them which may have contributed to the latter's lover preference were that in Configuration B the top quadrant was empty, the emergency VHF transceiver and the VHF direction finder were both out of reach from a seated position, and the operational information display system occupied the lover left quadrant. The OIDS was, perhaps, not considered to be a crucial instrument.

Configuration D was chosen as first or third choice by four of twelve subjects. Configuration D was similar to Configuration A in that the VHF direction finder was within reaching distance from a seated position, and the shelf was clear. On the other hand, Configuration D was similar to Configuration B in that the emergency VHF transceiver was out of reach from a seated position and the large wind instruments and analog altimeter were not in immediate front view.

The final design produced by the experimenters appears to resemble Configurations C and D in that, except for the keyboards, there was a cleared shelf, an essentially empty top right quadrant, and a full bottom left quadrant. However, there were major differences in the locations of the large wind instruments, and of several models which were placed along the mid-line between the right and left sides of the console. One can see major differences in terms of the location for the navids monitor, the lamp test module, the ILS monitor, the power switch, the video information panel, and the operational information display system. This suggests that subjects partially agreed with Configurations C and D even though they rated these configurations lov.

In assessing the subjects' choices of location we must consider the function of each model, the amount it is used, and whether it was a display or a control. According to experienced controllers, the most frequently used displays are the radar screen, the digital altimeter, and the wind instruments, while the analog altimeter is rarely used if the digital altimeter is present. The most frequently used controls are the keyboards, the hotline modules (on the left of the console), the direct access modules, and the CCFM. The power switch, the VHF direction finder, and the emergency VHF transceiver are rarely used.

From this one can conclude that the most accessible devices should be the keyboards, the hotline modules, the radar screen, the wind instruments, and the digital altimeter.

Two of the most frequently used controls, the direct access modules and the CCFM's, were two of the three models that had been split by the subjects and placed in separate locations. This probably reflected the fact that they would be used by both controllers in those circumstances where the station was operated by two controllers. The instructions to the subjects implied that the workstation was to be used by the subject alone, but this was not explicitly stated and some subjects probably interpreted the instruction otherwise.

7.0 CONCLUSION

The procedure of designing a workstation by constructing a model console requires the controller to be actively involved in the design process. The controller can make use of past experience, but at the same time the procedure compels him or her to avoid demanding that the workstation incorporate features that are mutually inconsistent. As such the procedure is preferrable to a questionnaire-style approach where incompatible choices in location may easily be overlooked, and where in fact it is too easy to demand unobtainable perfection.

In terms of producing a final design however, it is also clear that consensus among controllers on an agreed design of workstation does not exist. At the last resort final decisions must be made by the designer. Nevertheless, the data obtained from the experimental procedure does bring to light certain aspects of the controllers' requirements which might otherwise be overlooked by the designer.

The procedures of asking controllers to rate and to rank designed workstations do not appear to be very fruitful. There seems to be little argeement between the results of the two procedures and no way of deciding, given those circumstances, which is better. Furthermore, the subjects of this experiment appeared to disregard the experimenter-designed configurations in constructing their own consoles.

Our final conclusion therefore is that this study has demonstrated hov experienced controllers can contribute a useful role in designing workstations by following the procedure that we have called the subject-design procedure.

8.0 REFERENCES

HUCHINGSON, R.D. 1981. New Horizons for human factors in design. New York: McGrav-Hill.

KANTOWITZ, B.H. and R.D. SORKIN. 1983. Human factors: understanding people-system relationships. New York: John Wiley and Sons.

Appendix 1

Inventory of models

1. Video information panel (VIP):
   displays airway charts and aeronautical information, emergency procedures, and other information.

2. Video information panel selector switch (VIP selector):
   selects information to be displayed on video information panel.

3. Radar control box (RCB):
   controls operation of radar screen.

4. Numeric function panel (NFP):
   controls functions on radar screen.

5. Quick action panel (QAP):
   controls functions on radar screen.

6. Alpha-numeric key pack (ANK):
   enters information on radar screen.

7. QWERTY keyboard:
   enters input to video terminal.

8. Operational information display systems (OIDS):
   displays information relating to operating stations.

9. Digital clock:
   displays time of day.

10. Small wind direction and velocity indicators.

11. Large wind direction and velocity indicators.

12. Digital altimeter display system (DADS):
    displays barometric pressure at operating station.

13. Altimeter:
    provides analog alternative to digital altimeter.

14. Runway visual range monitor (RVR):
    indicates runway visibility.

15. Very high frequency direction finder (VHF/DF):
    indicates aircraft direction.

16. Instrument landing system monitor (ILS Monitor):
    monitors flight paths and radio beams for instrument landings.

17. Navids monitor:
indicates operating conditions of navigational facilities.

18. Radio frequency modules (five items):
provide communication with pilots.

19. Emergency VHF transceiver:
provides emergency backup for main transmitter.

20. Hotline modules (six items):
provide instanteous communication with adjacent units and sectors.

21. Direct access modules (DAM) (eight items):
provide normal communication with units and sectors.

22. Common circuit and function module (CCFM):
provides communication with armed forces.

23. Telephone dial pad:
provides conventional telephone communication.

24. Speaker:
small square loudspeaker.

25. Loudspeaker:
large rectangular loudspeaker.

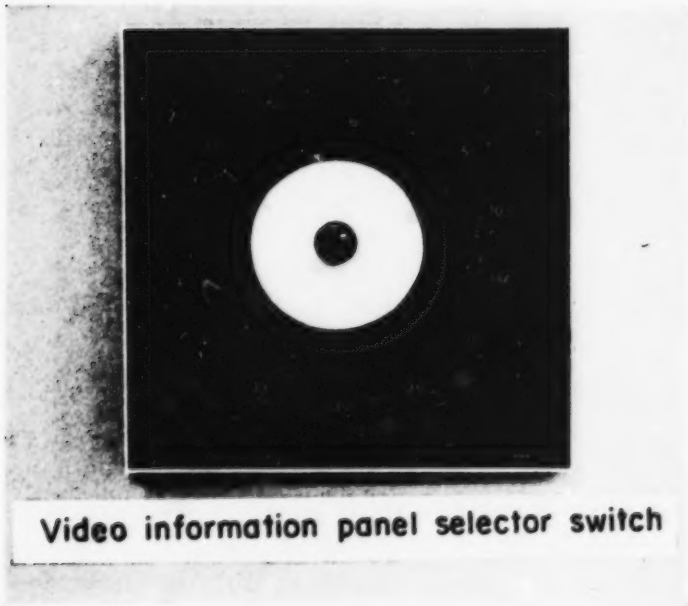
26. Power switch:
controls power for the workstation.

27. Lamp test module:
tests lighting of devices with back lighting.

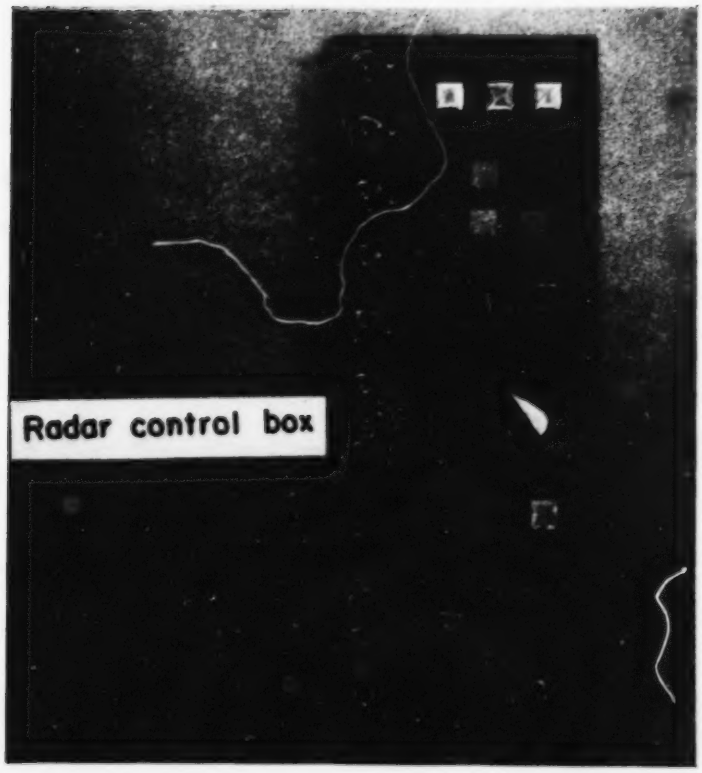
28. Data strip container:
stores dead flight strips.

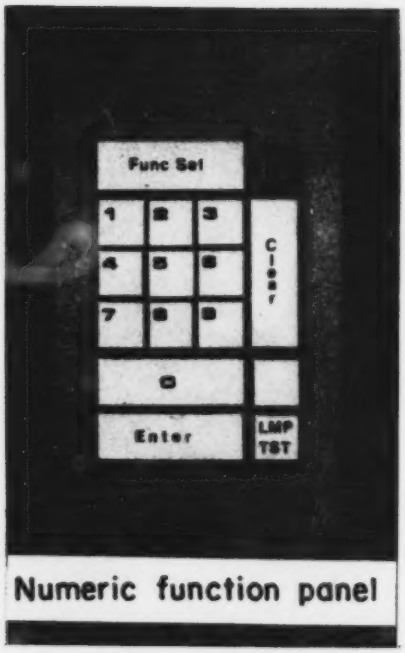
Appendix 2

Photographs of models

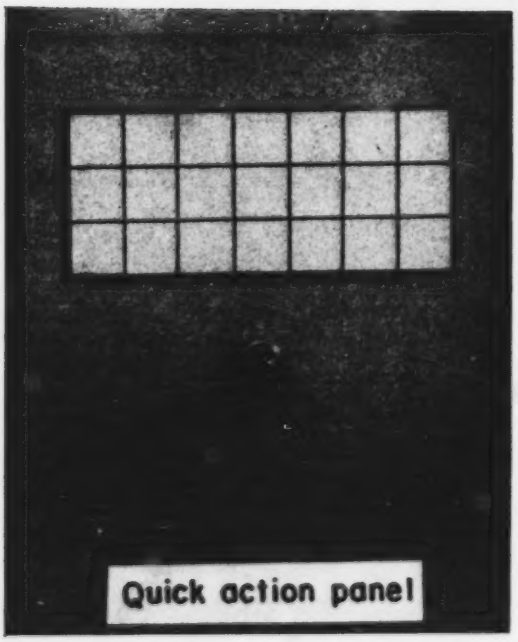


Video information panel selector switch

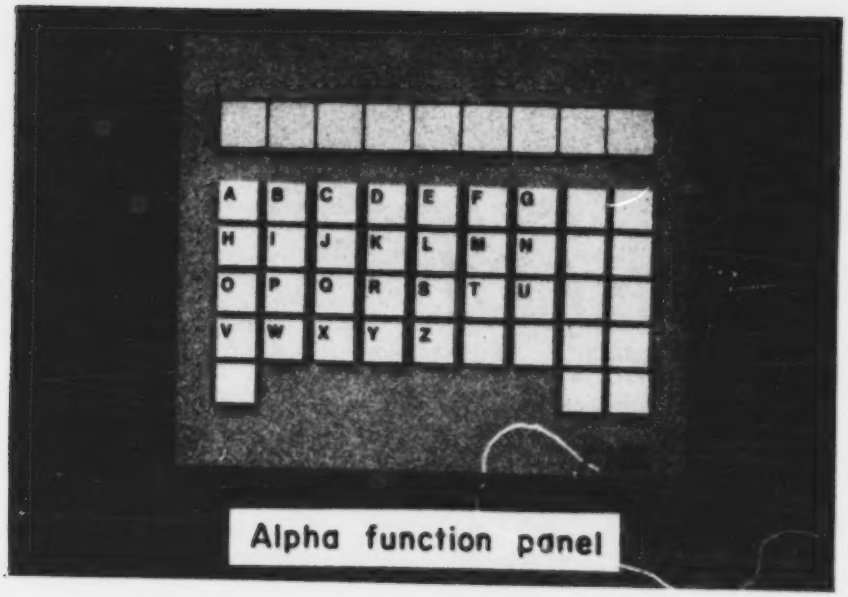


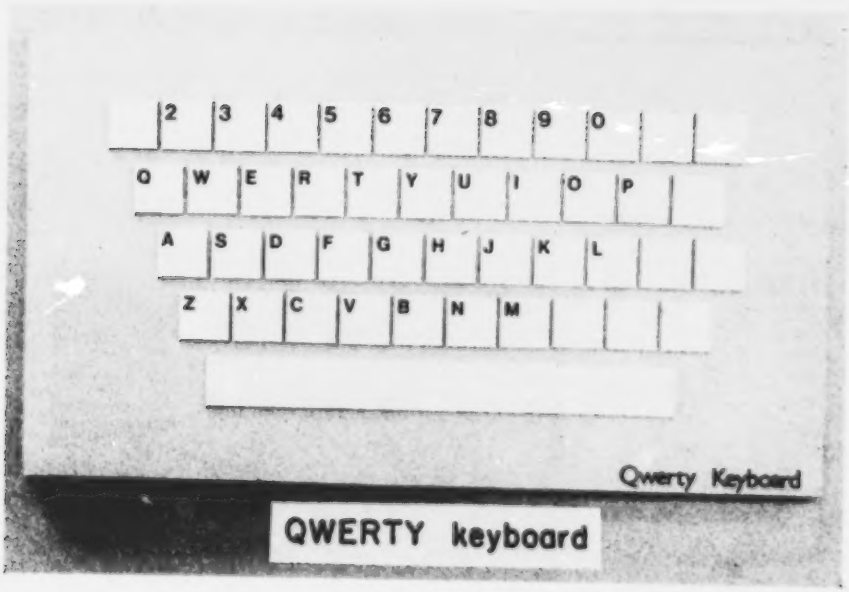


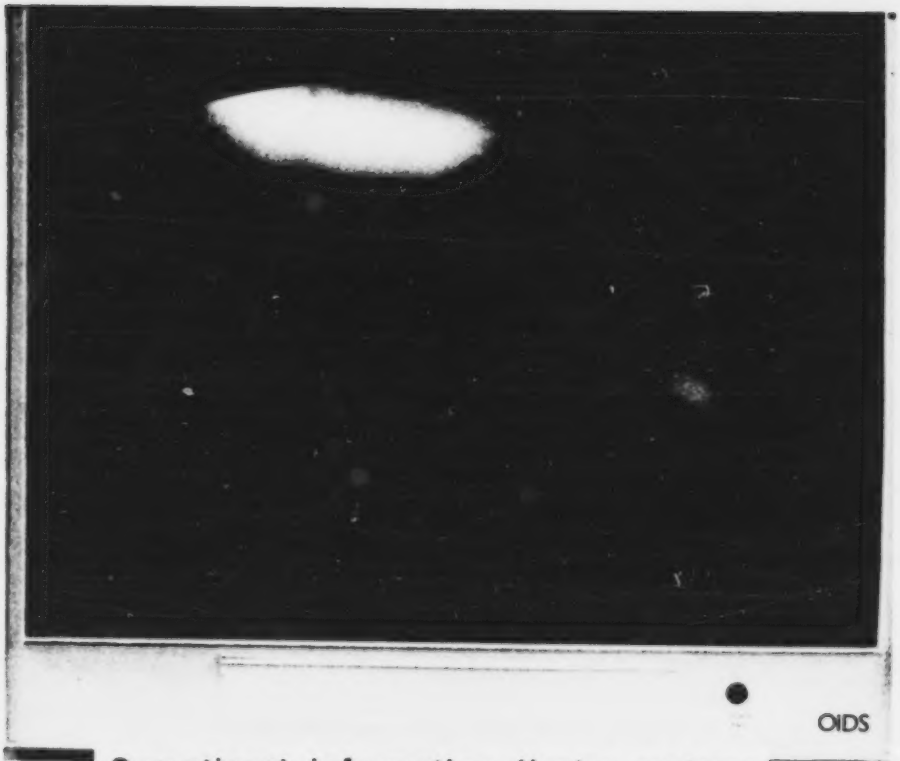
Numeric function panel



Quick action panel

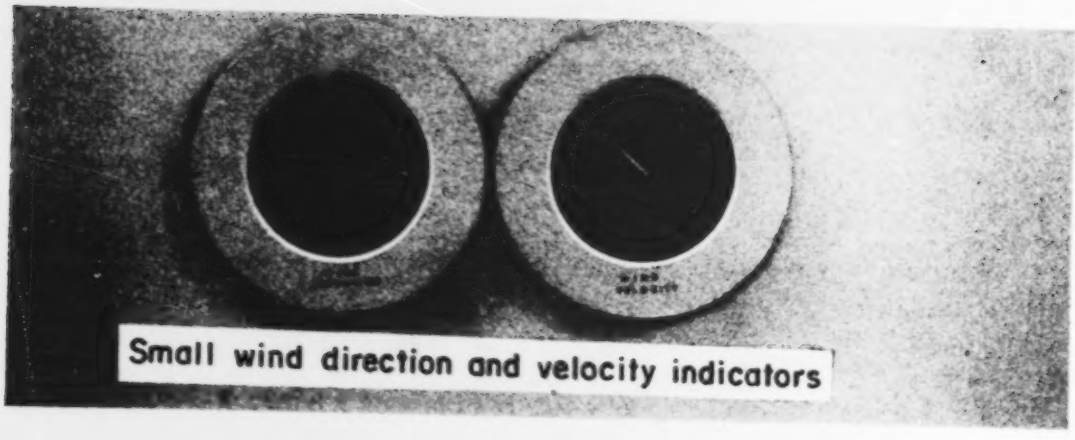

A B C D E F G
H I J K L M N
O P Q R S T U
V W X Y Z
Alpha function panel


2 3 4 5 6 7 8 9 0
Q W E R T Y U I O P
A S D F G H J K L
Z X C V B N M
Qwerty Keyboard
QWERTY keyboard

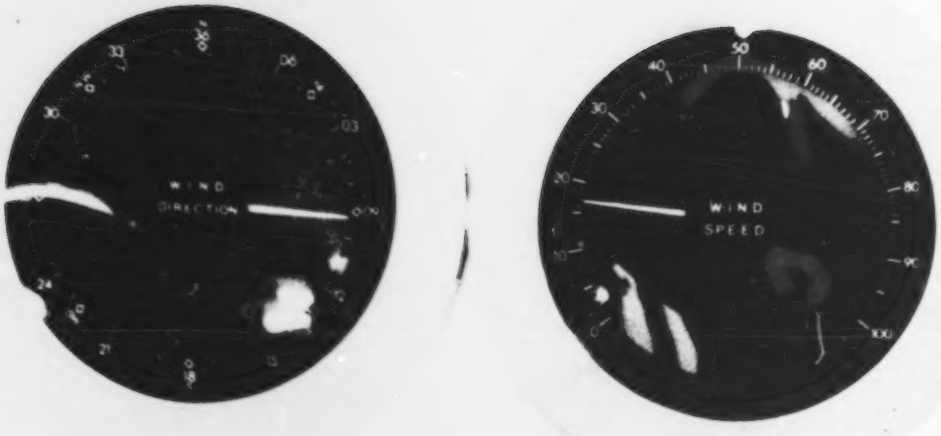


Operational information display systems

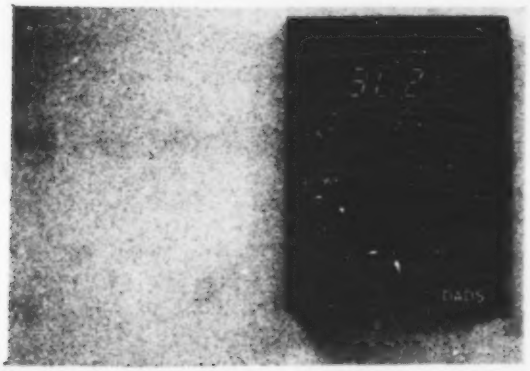
Digital clock



Small wind direction and velocity indicators

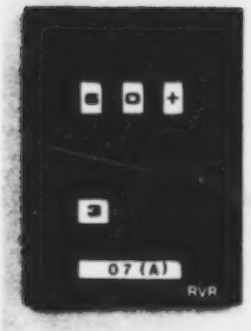


Large wind direction and velocity indicators

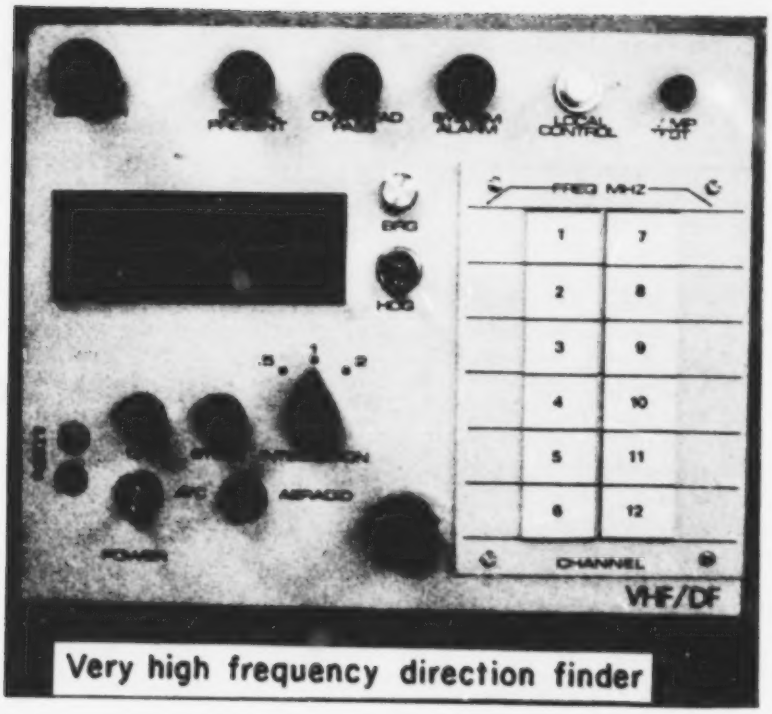


Digital altimeter display system

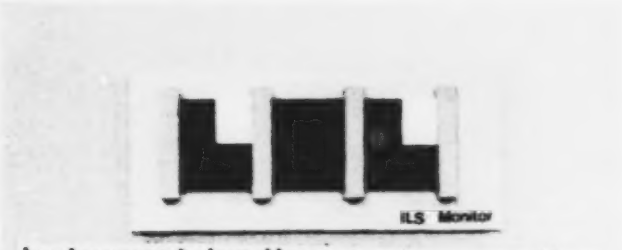
Altimeter



Runway visual range monitor

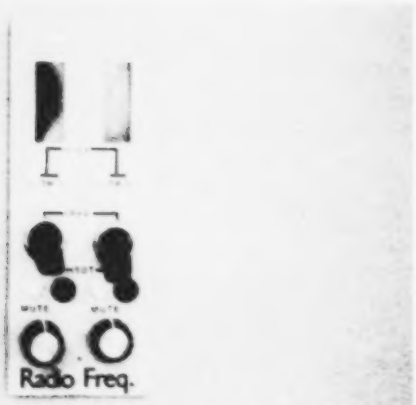


Very high frequency direction finder



Instrument landing system monitor

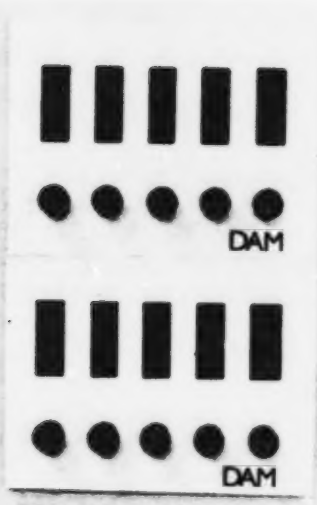
Navids monitor



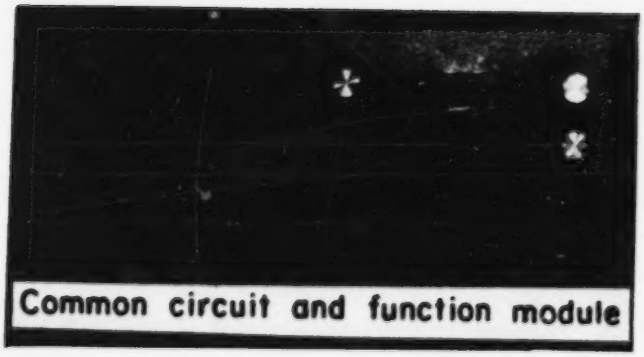
Radio frequency modules

Emergency VHF transceiver

Hotline modules



Direct access modules

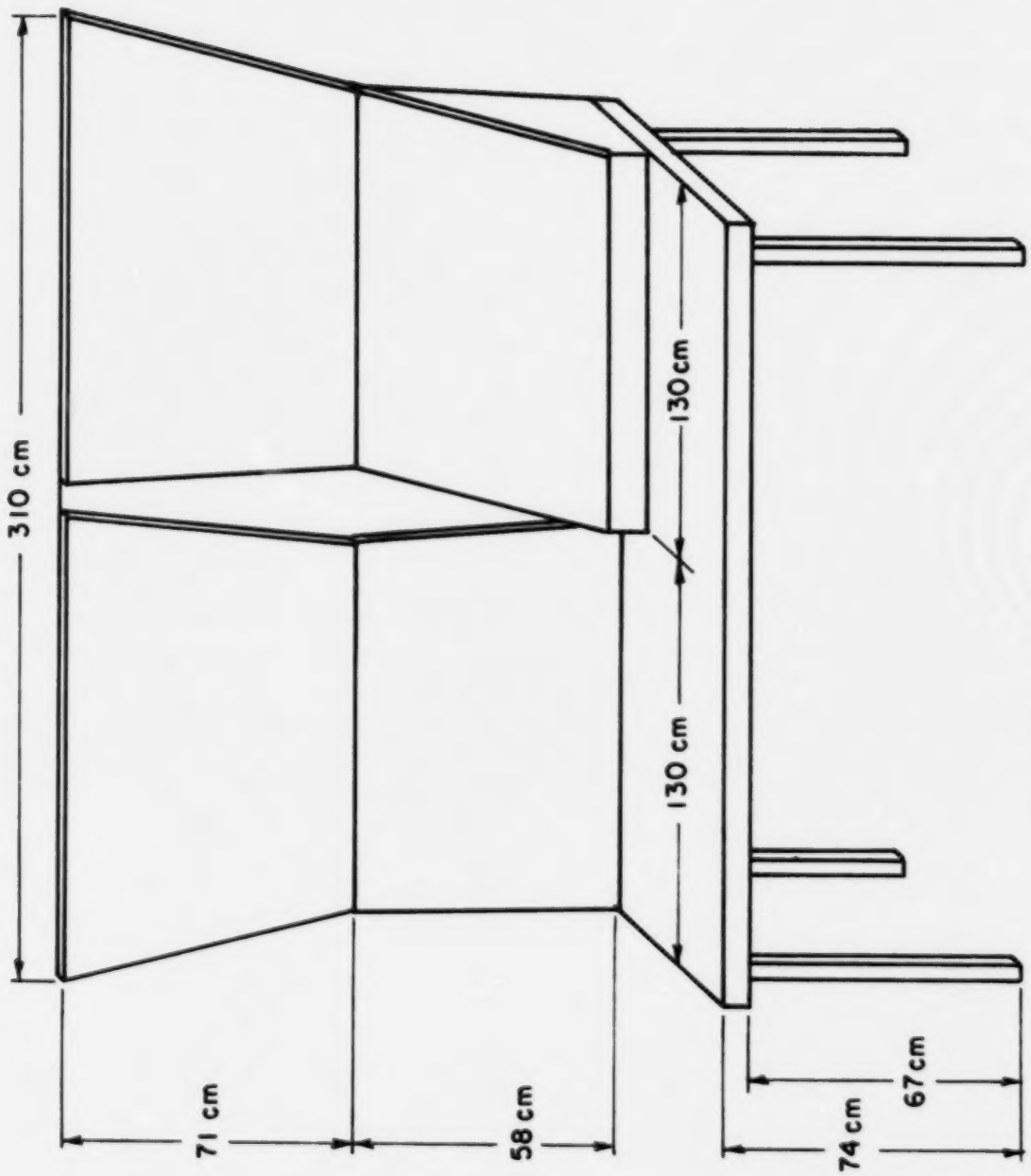


Common circuit and function module

Telephone dial pad

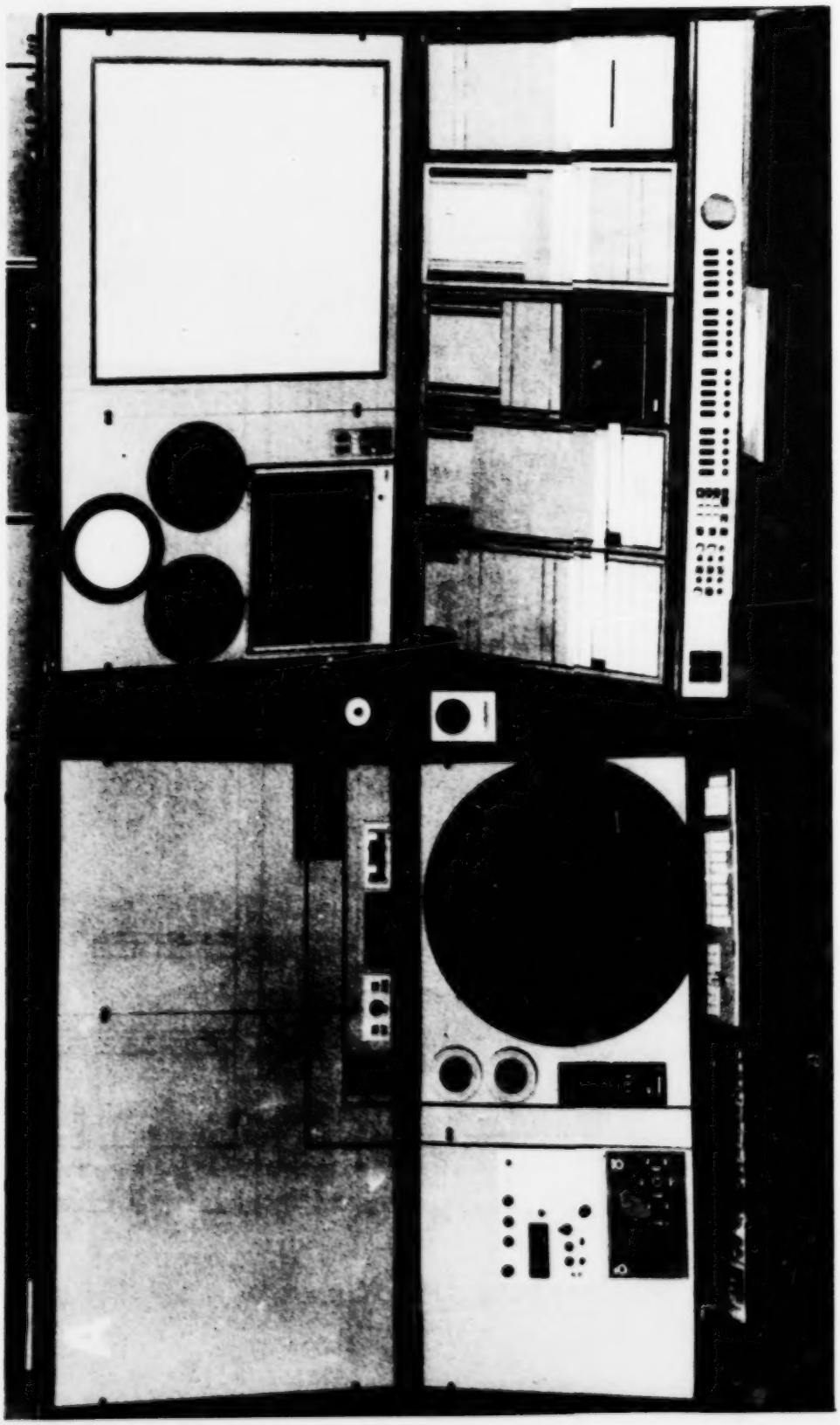
Power switch

Appendix 3



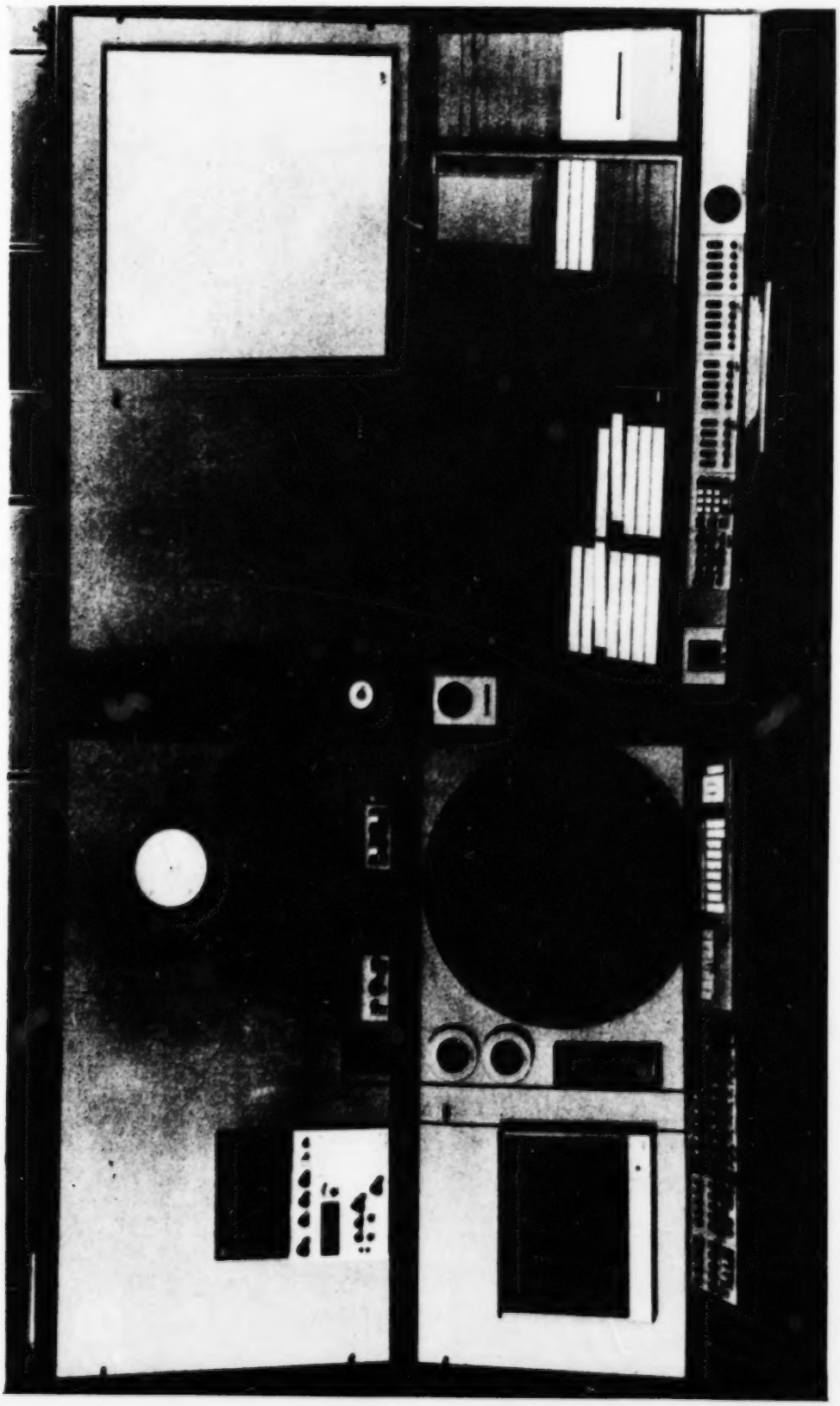
Dimensions of blank console

Appendix 4



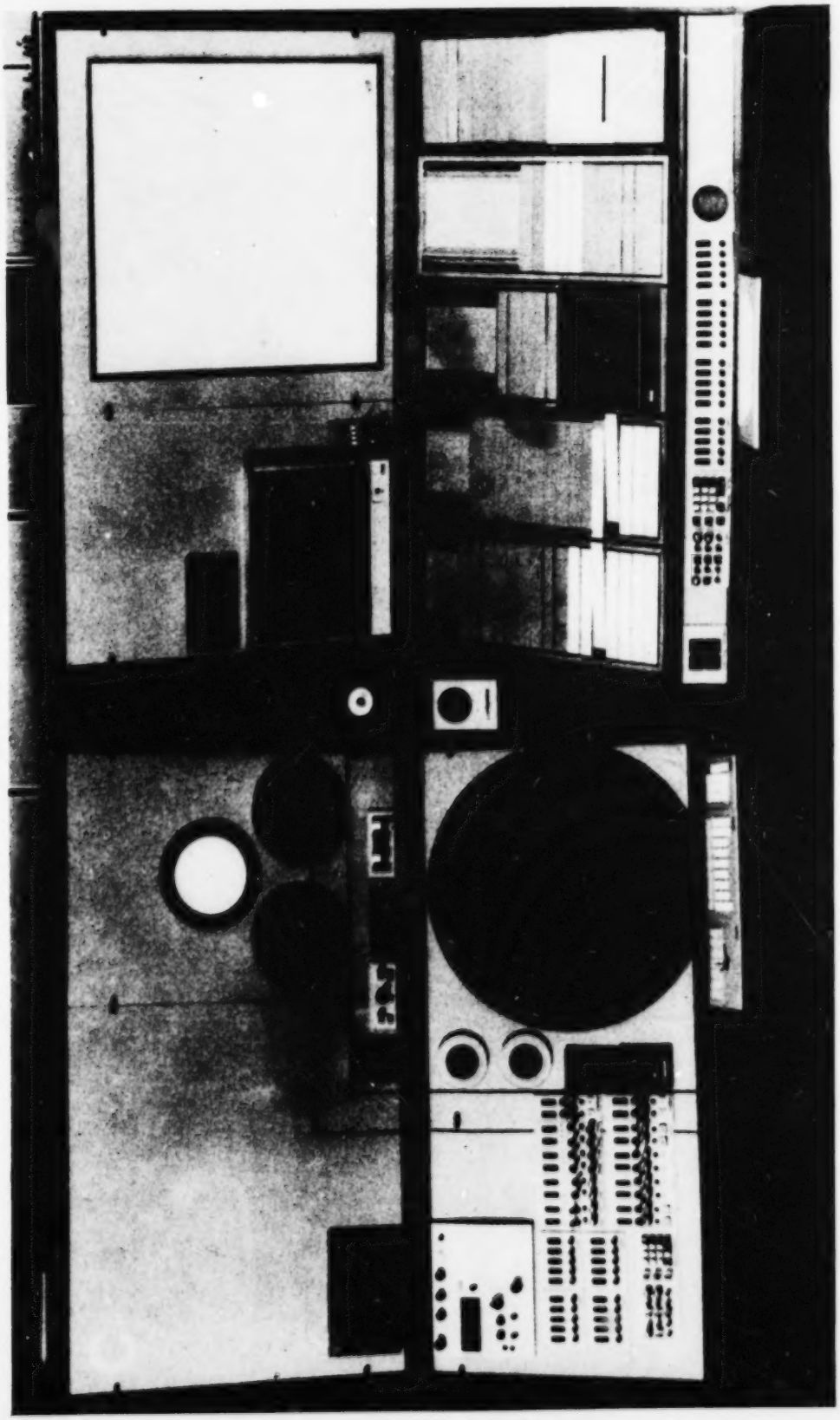
Experimenter-designed configuration A.

Appendix 5



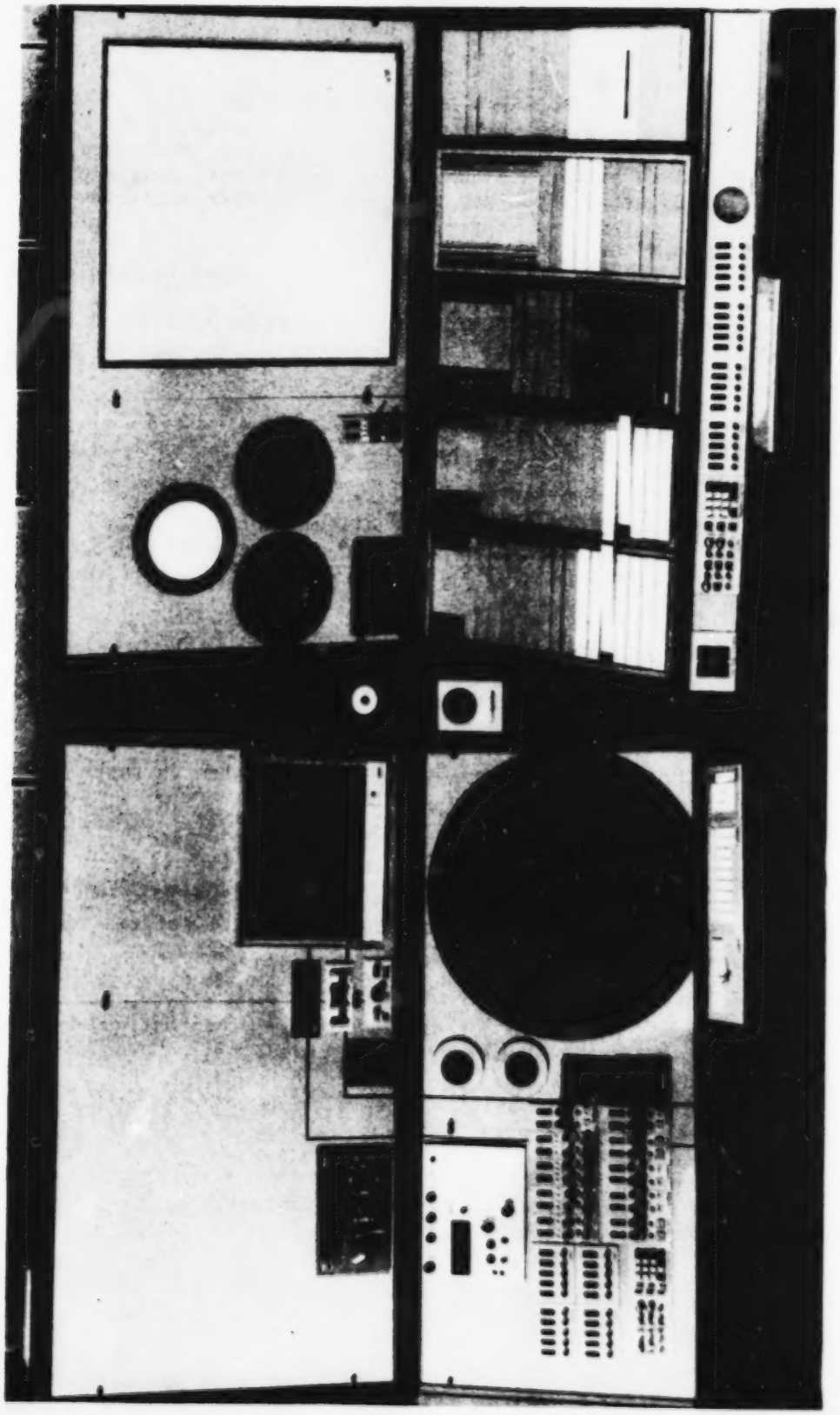
Experimenter-designed configuration B.

Appendix 6



Experimenter-designed cofiguration C.

Appendix 7



Experimenter-designed configuration D.

Appendix 8

Questionnaire form and responses

This last task will require that you identify your preference regarding the quality of certain components used at the controller workstation. In Question 7 you may indicate your preferences for a number of items.

Question	number responding
1. Indicate preference for the design type of workstation.	
(a) modified wrap-around type (as in mock-up)	12
(b) in-line type	0
2. Indicate preference for type of radar display.	
(a) circular	12
(b) rectangular	0
3. If a supplementary display was made available for the workstation, which of the following would you prefer?	
(a) 14 inch display	6
(b) 20 inch display	6
4. In reference to the above, indicate the position you favor for the supplementary display.	
(a) above the current display at the radar position	6
(b) above the data board position	6
5. The OIDS display on this mock-up is of the same size as that currently used in the field. Do you think it ...?	
(a) is adequate	11
(b) should be smaller	0
(c) should be larger	1
6. Do you favor the use of colour when displaying OIDS information?	
(a) yes	12
(b) no	0

7. If colour becomes available for display of OIDS information, which of following types of data should be colour-coded?
   (a) altimeter setting
   (b) unserviceability of navids
   (c) weather below vfr minima
   (d) special messages
   (e) eye-catchers
       (to emphasize changes in information content,etc)
   (f) hazards to navigation

8. For the display of wind direction and speed information, which of the following do you favor?
   (a) Analogue readouts 6
   (b) Digital readouts 6

9. The angle of the communication panel on the radar console is on an incline of ten degrees to the horizontal. Do you favor...?
   (a) More incline 1
   (a) Less incline 0
   (b) Same incline 11

10. Is the wrist and forearm room between the edge of the communications panel and the edge of the radar console table sufficient? Indicate preference.
   (a) Adequate 11
   (b) More 0
   (c) Less 1

11. Considering that time is available from other sources, do you think that a digital clock is a necessary instrument at the workstation?
   (a) Yes 10
   (b) No 2

12. How should the keyboards be installed on the console table?
   (a) Imbedded on the console table and laid flat 3
   (b) Raised fromthe console table and inclined 9

13. Indicate your choice for the location of storage slots for storing inactive strips.
   (a) Right side 2
   (b) Left side 7
   (c) One at each side 3

14. Indicate the type of foot switch you prefer for air-ground communications.
   (a) Bar type 2
   (b) Pedal type 10

Appendix 9

Models categorised by consensus of location
on the horizontal axis in the subject-redesign procedure

high consensus	medium consensus	low consensus
VIP selector	VIP display	large wind indicators
NFP	RCB	altimeter
QAP	ANK	CCFM (1 part)
radio frequency modules	QWERTY keyboard	
DAM (2 parts)*	OIDS	
data strip container*	digital clock	
	small wind indicators	
	DADS	
	RVR	
	VHF/DF	
	ILS monitor	
	navids monitor	
	emergency VHF	
	hotline modules	
	CCFM (1 part)**	
	telephone dial pads (2 parts)	
	speaker	
	loudspeaker	
	power switch	
	lamp test module	

Note. In the subject-design procedure consensus was medium for models marked (*) and low for the model marked (**).
See Appendix 1 for the meanings of the abbreviations.

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NOTES

13

DESCRIPTORS(KEY WORDS)/MOTS-CLÉS

Workstations, Airtraffic Control

14

SUMMARY/SOMMAIRE

Describes studies of techniques for eliciting operators' opinions in designing workstations.

15

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